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The geometry vs. the algebra of meaning: Gärdenfors vs. Jackendoff

In this paper Gärdenfors's geometric approach to meaning in natural language is compared to Jackendoff's algebraic one, and this is done against the backdrop of formal semantics. Ultimately, the paper tries to show that Jackendoff's framework is to be preferred to all others. The paper proceeds as follows. In Section 2, the common theoretical commitments of Gärdenfors and Jackendoff are outlined, and it is attempted to argue briefly that they are on the right track. In Section 3, the basics of the two frameworks to be compared are laid out, and it is assessed how they deal with some central issues in semantic theory, namely reference and truth, lexical decomposition, and compositionality. In Section 4, we get into the nitty-gritty of how Gärdenfors and Jackendoff actually proceed in semantic analysis, using an example of a noun and a verb (embedded in a sentence). In Section 5, the merits of Gärdenfors's empiricism when it comes to word learning and concept acquisition are assessed and compared to the moderate nativism of Jackendoff, and it is argued that Jackendoff's nativism is to be preferred. In the sixth section, the semantic internalism common to both frameworks is commented on.

Key words: meaning; geometric; algebraic; domain; function.

1. Introduction*

In this paper I propose to compare Gärdenfors's geometric approach to meaning in natural language to Jackendoff's algebraic one, and to do this against the backdrop of formal semantics. Ultimately, I will try to show that Jackendoff's framework is

* I am grateful to Ray Jackendoff and two anonymous reviewers for helpful comments on earlier drafts of this paper.

to be preferred to all others; however, as will become apparent, all three frameworks have much to offer in the way of explicating meaning.

Why compare specifically these three approaches? Well, formal semantics (cf. e.g. Chierchia & McConnell-Ginet 2000 or Larson & Segal 1995) is the dominant approach to meaning today, in addition to cognitive semantics. Among cognitively-oriented approaches, Jackendoff's and Gärdenfors's share the feature of being (partly) formalized, which makes them stand out with respect to other cognitive approaches, and at the same time makes them amenable to comparison with formal semantics. The goal of the paper is to propose which of the two partly formalized cognitive approaches should be preferred, and to assess how this approach compares with formal semantics.

I will proceed as follows. In Section 2, I will outline the common theoretical commitments of Gärdenfors and Jackendoff, and attempt to argue briefly that they are on the right track (although they are often opposed to the mainstream tradition consisting of generative grammar and formal semantics). In Section 3, I will lay out the basics of the two frameworks to be compared, and assess how they deal with some central issues in semantic theory, namely reference and truth, lexical decomposition, and compositionality. In Section 4, I will get to the nitty-gritty of how Gärdenfors and Jackendoff actually proceed in semantic analysis, using an example of a noun and a verb (embedded in a sentence). In Section 5, I will assess the merits of Gärdenfors's empiricism when it comes to word learning and concept acquisition and compare it to the moderate nativism of Jackendoff, arguing that Jackendoff's nativism is to be preferred. In the sixth section, I will comment on the semantic internalism common to both frameworks.

2. Common commitments

I have identified four overarching theoretical commitments that Gärdenfors's and Jackendoff's frameworks share (I leave a fifth one, internalism, to Section 6). I will state and comment on each one in turn.

Commitment 1. Conceptual structure is prior to language, in terms of evolution, ontogeny, and richness.

This is not something formal semantics can say much about, since it deals with meanings independently of their relation to concepts. However, some who would naturally be aligned with this tradition, such as Gauker (2011), deny it. It seems to be true, however. That conceptual structure is prior to language evolutionarily seems to be shown by the fact that languageless animals can in all likelihood con-

ceptualize (cf. Mareschal et al. 2010: Chapters 8–11). That conceptual structure comes before language in ontogeny is shown by similar data for babies (Mareschal et al. 2010: Chapter 12) and by Fodor's (1975: 55–64) argument that in order to learn a language, one already has to have a representational system at one's disposal. Finally, that conceptual structure is richer than language seems to follow from the fact that in communication more is often expressed and understood than is actually said, and also from the fact that language does not seem to be logically explicit enough to support reasoning.

Gauker (2011) claims that concepts come in only with the advent of language. This is not the place to offer an elaborate argument against this claim, but let me point out that the meanings of some words are abstract, which means they cannot be given in imagistic terms (as Gauker would have it), and yet if they were again given in language, this would lead to circularity. Gärdenfors and Jackendoff are aligned with the mainstream in concepts research in seeing words as mapping into concepts. They aim to explicate meaning in terms of an independently given conceptual structure, and this seems to be the right way to go.

Commitment 2. Semantics drives syntax.

In opposition to mainstream generative grammar (cf. e.g. Radford 2004), which sees syntax as the primary generative component and semantics as interpretative, Gärdenfors and Jackendoff both see semantics as the primary combinatorial engine, which syntax has evolved to express. Whereas Gärdenfors does not even talk much about syntax, devoting all his attention to semantics (and attempts e.g. to give a "syntax-free" account of word classes), Jackendoff sees syntax as "semi-autonomous": some syntactic phenomena, such as word order, have nothing to do with semantics, but many are semantics-driven (e.g. binding of a dependent element by an antecedent, cf. Culicover & Jackendoff 2005: Chapter 10). Also, Jackendoff assumes that syntax should be slim, that there should be only as much of it as is necessary to map meaning onto phonology, whereas the complexity of meaning, which mainstream generative grammar cum formal semantics often tries to handle in the syntax (e.g. quantifier raising), is accounted for in the semantics and its interface with syntax, where it, by my lights, rightly belongs.

Commitment 3. There is no sharp boundary between semantics and pragmatics.

This seems to be in line with some recent developments in philosophy of language (cf. Recanati 2010), although it is also hotly disputed (cf. Borg 2012). Gärdenfors mostly just takes this commitment for granted, but Jackendoff has several nice examples to demonstrate it (cf., amongst other places, his 2002: Chapter 12.2.). One

is the following: in the sentence *She jumped until the bell rang*, the jumping has to be construed as iterative. Why, if the verb *to jump* normally only entails a single jump? Because introducing a temporal bound (in the form of *until*) on an already bounded event (such as jumping) would make the meaning ill-formed if the event were not reconstrued as repeated, therefore making the verb into a process verb, which can be bounded. However, this is done online, via a pragmatic process of enrichment, so that "what is said" by the sentence obviously depends on pragmatic factors (an alternative would be to treat *jump* as polysemous, but then *every* verb which expresses a point-event would have to be treated as such, which is unwarranted). This seems to be a key example that refutes the semantic minimalism of Borg (2012) and others, which claims that "what is said" is determined only by semantics (what is encoded in the language) and some obligatory pragmatic processes, such as reference assignment to pronouns.

Commitment 4. Words are prior to sentences (developmentally and methodologically).

This is where the frameworks of Gärdenfors and Jackendoff are most sharply opposed to the formal semantic tradition, which takes sentences as the basic unit of analysis. For formal semantics, based as it is on formal logic and the idea of truth conditions, it is natural to start directly with sentences, and treat single words as abstractions from them. However, Jackendoff and Gärdenfors show that much can be said about lexical semantics before one even gets to sentences (indeed, Gärdenfors 2014 devotes almost the whole of its semantic theory to lexical semantics). And this approach seems to be on the right track: sentences are built from words that are available prior to them. If I utter *dog* out of the context of a sentence, you can still understand me, and you can manifest this understanding by a paraphrase (*man's best friend*, *four-legged furry tail-wagging pet that sometimes barks*, etc.) or by ostension (you can point to a dog, if one is available in the visible surroundings, or you can draw one, etc.). So, lexical semantics is a viable project, and preceeds phrasal semantics.

3. Geometric vs. algebraic

In this section I lay out the basics of Gärdenfors's and Jackendoff's semantic programs and assess how they deal with certain key semantic phenomena.

Both Gärdenfors and Jackendoff propose to explicate meaning, not in terms of relations of words and sentences to entities in the world (as in formal semantics), but in terms of conceptual structure that the words and sentences map into. Howev-

er, their respective takes on this structure are importantly different. Whereas Jackendoff champions an *algebraic* approach, focusing on conceptual *functions* which take arguments, Gärdenfors adopts a *geometric* approach, focusing on conceptual *domains* and their spatial configurations. I will start off by introducing Jackendoff's approach.

Jackendoff divides the business of explaning meaning (and therefore divides in the same way our mental make-up) into Conceptual Structure (CS) and Spatial Structure (SpS). CS is a hierarchical combinatorial structure, an algebraic recursive system, consisting of conceptual functions and the arguments they take. It is a system of basic concepts, basic units of thought, which, when composed, constitute the meaning of words and sentences. SpS, on the other hand, encodes "the integration over time of the shape, motion and layout of objects in space (and possibly the forces among them)" (Jackendoff 2002: 346). SpS is primarily, but not exclusively, visual, as it also receives input from the haptic, proprioceptive, and auditory systems. It is much more flexible and abstract than the usual "visual image", since it has to encode the shape of objects (and also actions and scenes) in a way that enables us to recognize the object from different distances and perspectives (and to find our way in a scene from different points of view). It also has to encode the parts of objects which are not visible at the same time, and has to allow for variations in shape. SpS overlaps with CS "in that the notions of physical object, part-whole relationships, locations, force, and causation have reflexes in both systems" (Jackendoff 2002: 347). I have dwelled here for a while on SpS in order to show that there is a geometric aspect to Jackendoff's framework too – it is just that it is not the whole story. The main burden of explicating meaning is carried by CS.

CS is the organization of conceptual functions and arguments. Some main functions (corresponding to the ontological categories of State and Event) are: (i) the core functions: BE, GO, STAY,[1] etc.; (ii) the aspectual functions: INCH (for "inchoative") and PERF (for "perfective"); (iii) the causal functions: CAUSE, LET, HELP, etc. These functions are then used to build the meanings of verbs (and other argument-taking words).[2] So, for example, the sentence in example (1) would be analyzed as 'Curiosity caused the cat to come to be dead'.[3]

[1] In accordance with standard practice, the names of concepts are given in capitals.

[2] As a reviewer pointed out, these functions are not all independent of each other, e.g. GO and STAY are incompatible, INCH and PERF are the reverses of each other, etc. I accept the reviewer's suggestion that they might be related by meaning postulates.

[3] For some details of the formalism Jackendoff employs in representing the meaning of a sentence, see next section.

(1) *Curiosity killed the cat.*

Here, three of the above listed functions are used: CAUSE, INCH ('come to be') and BE. CAUSE takes two arguments, an object (curiosity, an abstract object) and an event, to deliver an event – the event of causing something to happen. The event that is the second argument of CAUSE, the event of the cat coming to be dead, is further decomposed into the state of the cat being dead and the conceptual function INCH that applies to it to deliver the event of the cat becoming dead. In such a way the meanings of sentences (and particulary verbs) are decomposed into basic units of thought, whose meaning is in turn given by their principles of combination and the ability to license inferences. In addition, the conceptual functions can receive a "field feature" that specifies the semantic field in which the event or the state is defined. The field of the above sentence is the field of change of, i.e. ascription of, properties. Some other fields are the field of spatial location and motion and the field of possession. Jackendoff claims that the apparatus needed to account for spatial location and motion generalizes to many other semantic fields (cf. Jackendoff 1983: 188). So, e.g. the causative function applies primarily in this field (*Beth threw the ball out of the window = Beth caused the ball to go out of the window*, cf. 1983: 175), but can be transferred to the domain of ascription/change of properties.

As for Gärdenfors, his framework is a geometric formalization of cognitive semantics, an approach to the study of language and mind initiated by such thinkers as Lakoff (1987) and Langacker (1987; 1991). The guiding idea of this approach is that meaning is to be explicated in terms of spatial, sensory-motoric structures (often called "image schemas"). A certain affinity between this approach and Jackendoff's is identifiable here (which opposes them both to formal semantics), since Jackendoff, as was seen above, introduces SpS, and also claims that the spatial field has a certain primacy. Thus both approaches connect meaning/concepts to perception and action (since the spatial systems feed directly into the perception and action systems), which formal semantics has not been able to do. However, while Jackendoff still reserves room, and a lot of it, for abstract, algebraic representations, cognitive semantics is more radical, and goes all the way in reducing meaning to spatial structures.

The central notion for Gärdenfors is one of domain, which is what his "conceptual spaces", as the mind's similarity spaces, are partitioned into. Domains are organized by dimensions, which represent dimensions of variation among objects. A domain is defined as "a set of integral dimensions that are separable from all other dimensions" (Gärdenfors 2014: 22, cf. Gärdenfors 2000: 26). Two dimensions are

said to be integral if one cannot assign an object a value on one without assigning it a value on the other. Dimensions are separable if they are not integral.

Domains (more precisely, values on their dimensions) are what the meanings of words map into. Gärdenfors (2014: Chapter 3) identifies the following domains: emotional, visuospatial, force and action domains, object category space, value domain, goal and intention domains, age and time and, finally, the event domain. Each has a structure that accounts for the meaning of a relevant class of words. More precisely, words refer to regions within domains (for example, *red* refers to a region of the color domain, which is a subdomain of the visuospatial domain). It is hypothesized that most words (except for nouns) have their meaning in a single domain, and that the regions to which they refer are convex. A convex region is such that for any two points in it, a third point between the first two also belongs to the region. Basically, the idea is that if two objects or actions in a domain are examples of a property, then whatever object or action is located between them in this domain is also an example of the property.

Objects are represented as points in a conceptual space. The closer they are, the more similar they are. Similarity is a crucial notion for Gärdenfors's theory, and is defined as "a function of distance in a conceptual space" (Gärdenfors 2000: 110). The notion of similarity is Gärdenfors's way of adopting a prototype theory of concepts. When a conceptual space is partitioned by a "Voronoi tessellation", then the location at the center of a region corresponds to the protoypical meaning of a word, to which the other meanings are more or less close/similar. Jackendoff also accepts the insights of research into prototypes, which can be seen by his work on preference rule systems and cluster concepts (Jackendoff 1983: Chapter 8; Jackendoff 1989: Section 7; Jackendoff 2002: Section 11.6.).[4] I think it is indeed important to accept these insights, even though they challenge a set-theoretical notion of categories, given in terms of necessary and sufficient conditions.

So these are the outlines of the two approaches, as I see them. How do they deal with some central issues in semantics?

[4] A reviewer raised the question how prototypical structures are combined with algebraic compositions in the Jackendoffian framework. I would respond that algebraic compositions are the skeleton of meaning, and prototypical structures are an additional layer, needed for some concepts. The reviewer countered that "adding prototypical structure would be needed for most concepts and would involve adding some geometric structure. Thus Jackendoff's position cannot be described as fully algebraic". I would respond that adding prototypical structure does not necessarily entail adding geometric structure, since prototypical structures are given as defeasible rules. But perhaps a combination of algebraic and geometric structure would be advantageous.

1. Lexical decomposition

As was clear from the above, Jackendoff is an all out advocate of lexical decomposition. He thinks semantic analysis should aim to find the primitives that build the meanings of words and sentences (i.e. the conceptual functions and arguments). The ultimate goal of his Conceptual Semantics is to identify the basic constituents of thought (i.e. meaning), the vocabulary of the language of thought. As for Gärdenfors, he seems to be in line with Lakoff's (1987: 279) claim: "Our conceptual system ... has foundations, but no primitives". The foundations of this system are the domains and the regions therein that the words of our language refer to – but they are not broken up into primitives.

What is the motivation for the search for primitives? For Jackendoff, it is the learnability of meanings/concepts. The idea is that we can only account for the potentially infinite number of the concepts we can learn by assuming that they are built out of a relatively small innate base of primitives. Fodor (1975; 1998, etc.) hotly disputes this view. The subtitle of his 1998 book is "Where cognitive science went wrong", and he identifies the wrong direction that cognitive science has taken as the assumption that concepts are composite. If he is right, Jackendoff's program is a non-starter,[5] and the only path left (assuming that Fodor's nativism is also a non-starter, as most cognitive scientists agree) seems to be Gärdenfors's: "the development of semantic knowledge can appropriately be described as an increasing set of separable domains" (Gärdenfors 2014: 66). In other words, a Gärdenforsian approach takes it that development starts with a similarity space (the dimensions of which have to be innate, as a reviewer pointed out) which then, based on the input from experience, gets partitioned into domains which serve as the basis for word meaning. In this framework, there are no primitives, but there is the developing "stuff" out of which word meanings are made. Incidentally, I think Fodor is not right, but the discussion of this point would require a separate article.

2. Compositionality

Jackendoff advocates the following principle regarding compositionality: the meaning of a sentence follows from the meanings of the words it consists of and the way they are combined plus independent constraints on conceptual well-formedness

[5] A reviewer disagreed here, but I think the opposition between Fodor and Jackendoff over the years (decades) makes this clear. As the reviewer him/herself points out, Jackendoff's analyses of words into conceptual structures do not correspond to any interesting syntactic structures, since he is not a proponent of Generative Semantics. There is, therefore, no way to combine Jackendoff's and Fodor's views at some "morphosyntactic" level.

(Jackendoff 2002 calls it "enriched composition"; Jackendoff 2019 calls it "autonomous semantics"). The bite of this approach can be seen on the above example: *She jumped until the bell rang*. The meaning of the sentence, implying multiple jumps, follows not just from the meaning of the individual words and the way they are combined but also from an additional conceptual well-formedness condition: a point-event cannnot be additionally bounded.

Gärdenfors concurs with this position (germane as it is to the whole of cognitive semantics). He says that "combining meanings often involves *transformations* of the meanings of the components" (2014: 241, italics in the original), which is exactly what happened in the example sentence. However, Gärdenfors also makes some more controversial points regarding compositionality.

One is that, on his account, compositionality is generated not from the meanings of the words but from domains (cf. 2014: 243). He says (same page): "composing domains generates a product space, and the meanings of composite expressions can be located as regions of the product space".[6] This could be accepted by Jackendoff, as it expresses the basic independence of thought from language, which he also advocates. But he certainly would not accept the following claim of Gärdenfors: that all composition is ultimately metaphorical composition (cf. Gärdenfors 2014: 248). In metaphor, a homemorphic mapping is created between two disjoint spaces (e.g. LIFE IS A JOURNEY maps structure from the journey domain into the life domain). Gärdenfors claims that direct literal composition, as plain compositional product construction (e.g. *black cat*), and modifier-head composition, which modifies the modifier (e.g. *white wine*, which is not really white), are just special cases of metaphorical composition. "The first type need not modify existing spaces. The second modifies spaces that are naturally overlapping. Finally, the metaphors ... require establishing homeomorphic correspondences between the disjoint spaces" (Gärdenfors 2014: 248).[7]

I believe that Jackendoff would say that this goes too far, and concedes too much to the metaphor-happy approach of Lakoff and colleagues. Is *He is the president* really a special case of *Juliet is the sun*? Maybe, but I do not think so, and neither, I presume, does Jackendoff.

[6] What is referred to here are Cartesian products.

[7] A reviewer disagrees with this interpretation of Gärdenfors, but to my mind Gärdenfors is clear (2014: 248): "The composition discussed in section 13.1 is really a special case of the composition in section 13.2, which in turn is a special case of the composition in this section" (section 13.3, entitled "Metaphorical Composition").

3. Reference and truth

Finally, how do these two authors see reference and truth? Their internalism will be the subject of Section 6, but a few points can be made here.

For Jackendoff, we refer to the world as conceptualized. "The intended reference of a declarative sentence is a situation (an event or a state of affairs)" (2002: 326). Further, "it makes sense to regard a clause as referentially satisfied by a conceptualized situation. The judgement of the truth value of a declarative sentence then follows from how it is referentially satisfied" (2002: 327). Finally, "the category corresponding to a sentence is an Event or State rather than a truth value ... . A truth value can be seen as the evaluation of the Event or State expressed by the sentence with respect to the world as conceptualized" (2002: 364).

Gärdenfors reasons along the same lines, but in a geometric framework. He says:

> The meaning of an atomic sentence consisting of a predicate and a name ... can thus be represented as an assignment to an object of a location in a certain region of conceptual space. ... Such a predicate is *satisfied* by an individual just in case the location function locates the individual at one of the points included in the region assigned to a predicate. (Gärdenfors 2000: 274, fn. 142)

As we can see, both Jackendoff and Gärdenfors propose mentalistic versions of model theory. However, Gärdenfors's geometric approach is open to some devastating objections from Gauker (Gauker 2011: Chapter 3), to which Gärdenfors, to my knowledge, has not responded. I will not repeat all these objections here, but will relate one of Gauker's examples, which purport to show that "it is not possible to identify judgements with structures definable in terms of similarity spaces" (Gauker 2011: 92). Gauker says:

> So if I accept what you say when you tell me 'Some cats like milk', I have to reconfigure the points in my similarity space or the boundaries between regions in such a way that some of the points representing cats lie within the *likes milk* region. ... This means that that I have to move some of the points representing cats into the *likes milk* region. ... The trouble is that if I learn that some cats like milk merely through being told, rather than by observing cats' behavior for myself, I have no basis for moving any particular points, rather than others, into the *likes milk* region. ... In general, the similarity space theory of concepts allows the representation of general facts only insofar as these representations are grounded in in particular facts about particular objects. This is an unacceptable limitation. ... (Gauker 2011: 107)

Due to the severity of this objection, I believe Jackendoff's algebraic approach is preferable to Gärdenfors's geometric one. What Gauker's objection shows is that

Gärdenfors's theory cannot represent general facts independently of particular facts they are grounded in. So, in talking about "some cats" we would in each case have to know exactly which cats we mean (Tom, Felix, etc.), which is an unpalatable constraint. But this constraint is unavoidable for the theory that treats concepts as regions (of objects, represented as points) in conceptual spaces. Jackendoff' framework, on the other hand, places no such constraint.

4. The nitty-gritty

In this section, I compare the ways Gärdenfors and Jackendoff would proceed in actual, detailed semantic analysis, using as test cases a noun and a verb.

As my example noun, I will pick *apple*. Formal semantics is not really big on lexical meaning, focused as it is on sentences, so it does not have much to offer here, besides treating *apple* as a simple predicate in the logical notation. Gärdenfors and Jackendoff would have more to say. Let us start with the more recent theory, Gärdenfors's. Gärdenfors (2014: 124) claims that an object category is determined by: (i) a set of relevant domains, (ii) a set of convex regions in these domains, (iii) prominence weights of the domains (dependent on context), (iv) information about how the regions in different domains are correlated, and (v) information about meronymic relations. So, in the case of *apple*, the analysis would proceed as follows (cf. Gärdenfors 2000: 102–103): it would be claimed that the meaning of this noun is represented in the domains of color, shape, texture, taste, fruit, and nutrition. The relevant regions would be: red-yellow-green for color, roundish for shape, smooth for texture, regions of the sweet and sour dimensions for taste, seed structure etc. for fruit, and finally values of sugar content, vitamins, etc. for nutrition. Information about how the regions in different domains are correlated would have the following form: "red correlates with sweet which correlates with high sugar content", etc. (these correlations, and the domains themselves, can be added as the child/adult learn more about the meaning of the word). The dependence of the prominence weights of the domains on context shows up in the following way: in *The child tasted the apple* the domain of taste comes to the fore, whereas in *The child threw the apple* the domain of shape is most prominent.

This articulation of the meaning of *apple* allows Gärdenfors to account for facts about hierarchical relations and analytic truth. So, for example, the fact that granny smith is a type of apple is accounted for by the fact that the regions associated with *granny smith* are subregions of the regions associated with *apple* (e.g. only the green subregion of the color domain is used). The analyticity of the sentence *Gran-*

ny smith is a kind of apple follows from this fact of inclusion.

How would Jackendoff deal with *apple*? Although his framework was originally developed to account primarily for the meaning of verbs (cf. Jackendoff 1983; 1990), he later (Jackendoff 2002) assimilated Pustejovsky's (1995) account of *qualia structure* to account for the meaning of nouns (and verbs too, cf. Jackendoff 2002: 373). Qualia are the basic building blocks of the representation of lexical (noun) meaning, and they come, according to Pustejovsky, in four (Aristotelian) types: formal,[8] constitutive, agentive, and telic. The formal quale includes the taxonomic structure, e.g. that an apple is a kind of fruit (also that a granny smith is a kind of apple). The constitutive quale includes information about the object's structural attributes, namely its sensory attributes (color, shape, texture, taste, etc.) and its meronimic structure. The agentive quale encodes information about how the object comes into existence: e.g. an apple grows from a seed. Finally, the telic quale encodes information about the object's characteristic activities and purposes: e.g. an apple is for eating.

It is easily seen that a Jackendoff (-Pustejovsky)-style analysis covers much the same ground as Gärdenfors's, when it comes to this noun. And it can account for hierarchical relations and analyticity in a similar manner. Also, it accounts for co-composition, e.g. the sentence *The child ate the apple* makes sense because an apple is a kind of fruit, and therefore edible thing.

It is interesting here to note how different both a Jackendoffian and a Gärdenforsian account are from a radically externalist account such as Millikan's (2017), where it is given up on identifying any kind of common mental structure between users of *apple* (because their bodies of knowledge about apples can diverge[9]), and *apple* is treated instead as a "unitracker"/"unicept" – a neural entity which tracks the appearance of the same external kind of thing again and again (in this case, apples).

So much for nouns. With regard to this word class, Jackendoff's and Gärdenfors's framework seem to be on a par (and both are severely wrong if externalism is right). Yet the real test for Gärdenfors's and Jackendoff's respective frameworks is how they handle the meaning of verbs (embedded in whole sentences). Here, to

[8] This is where the argument structure of a verb belongs.

[9] How persuasive it is that there can be radical divergence in the bodies of knowledge associated with such an everyday object as an apple, so that a search for common mental structure is abandoned, is questionable.

continue with the food examples, I will pick the verb *to butter*, embedded in the sentence in example (2):

(2) *Bill buttered the bread*.

First, what would formal semantics make of this sentence? In the spirit of Davidson's (1967) event-analysis, it would specify its meaning thus:

'Bill buttered the bread' is true if and only if ∃e (Buttering (e) & Agent (Bill, e) & Patient (the bread, e).

What this says is that the sentence is true if and only if there is an event, such that it is an event of buttering, and the Agent of the event is Bill, and the Patient of the event is the bread. The main virtue of this analysis is that it explains why certain other sentences follow from the sentence, such as *Bill did something* or *Something happened to the bread* – they do because it is straightforward to derive conjuncts from a conjunction. However, the analysis does not tell us anything further about the meaning of *butter*, it just repeats the verb as a predicate of the event that is described by the sentence. This is where Jackendoff's approach seems to offer more. Jackendoff's analysis of the sentence would look like this (cf. Jackendoff 2002: 367 and Jackendoff 1983: 185):

[$_{\text{Event}}$ CAUSE ([$_{\text{Object}}$ BILL], [$_{\text{Event}}$ INCH ([$_{\text{State}}$ BE ([$_{\text{Object}}$ BUTTER], [$_{\text{Place}}$ ON ([$_{\text{Object}}$ BREAD])])])])].

What this says is that Bill caused the butter to come to be on the bread. The representation of the meaning is given in terms of conceptual functions and ontological categories – ontological categories involved are specified by the subscripts and the functions are written in capitals ("BILL", "BUTTER", and "BREAD" are also in capitals because they can be treated as zero-place functions). "INCH", remember, is the inchoative function, glossed as 'come to be'. So, the whole sentence can be said to express an event of causation, where the object Bill causes an event of the object butter coming to be in a certain place, namely on the bread. The verb *to butter* is decomposed by the analysis into 'cause butter to come to be on (something)'. So, whereas the advantages of the Davidsonian analysis are preserved (the sentence is construed as representing an event, entailments can be derived[10]), we seem to get a deeper insight into the meaning of the verb, albeit a "skeletal" one, as Jackendoff puts it (2002: 369).

[10] That e.g. Bill did something follows from the fact that he caused something to happen, which is represented by the analysans. And likewise for other entailments.

As for Gärdenfors, he claims (cf. Gärdenfors 2014: Chapters 9 and 10) that underlying any verb meaning is a mental model of an event. Basically, this model contains an Agent exerting a force on a Patient, which results in an outcome (change in the properties of the Patient). The force exerted and the outcome are represented as a *force vector* and a *result vector*. According to his *single domain thesis for verbs* (2014: 184), a verb can only refer to a region of vectors in a single domain, therefore it has to refer either to the force vector or the result vector, but not both. So, the verb *to butter*, as a result verb, is to be interpreted as referring to the result vector of the event of buttering, that is, as expressing entry into the domain of being buttered. So, the interpretation of the sentence is that the Agent, Bill, by exerting force on the Patient, bread, causes it to change properties, namely to become buttered.

So far, so good. All three types of analysis offer an account of the sentence which is able to explain some features of its meaning. All construe the sentence as being about an event, all assign to Bill and the bread the roles of Agent and Patient respectively (Jackendoff does this implicitly, by structurally defining these notions, e.g. Agent is the first agument of CAUSE, cf. Jackendoff 2007: 203), all can handle the obvious entailments. We can also expand the sentence in this way: *Bill buttered the bread with a knife*, and all three accounts could easily represent this by adding the role of Instrument to the representation of the meaning of the sentence.

But consider now the sentence in (3):

(3) **Bill buttered the bread with a needle*.

Why does this sound anomalous?[11] It sounds anomalous, I would argue, because not just any kind of causing butter to transfer to the bread will do – it seems that the action of spreading the butter on the surface of the bread (-slice) is entailed, or at least strongly implied, by the verb, and spreading can only be done by an instrument that has a width above a certain threshold, which the needle does not have (would applying butter to the surface of the slice in microscopic amounts with a needle count as buttering? I would say "no").

This, I claim, causes trouble both for Jackendoff's and for Gärdenfors's account (it does not cause direct trouble for the formal semantic account, because this account makes fewer testable predictions about the meaning of *butter*, but it still has to explain the anomaly). Jackendoff's analysis of *to butter* as 'cause butter to come to be on' proves to be insufficient, because the manner of 'coming to be on' (i.e.

[11] I hope the reader shares my semantic intuition here.

the spreading) also seems to be part of the meaning of the verb. This can also be shown by asking oneself if pushing a piece of hard butter onto a surface would count as buttering it – it would not, by my lights, although it would satisfy the analysans 'cause butter to come to be on'. Jackendoff recognizes this problem, saying that "functional decompositions such as [the one above] are only skeletal, and there is the usual problem of 'completers'" (2002: 369). The way out would have to be either to enlarge the functional decomposition in order to account for the spreading element, or to relegate this element to SpS. However, further specifications will have to be made, e.g. that buttering the bread cannot be done by placing a packaged piece of butter onto the bread (although this would also satisfy 'cause butter to come to be on bread'), or that spreading the butter all over the external surface of a loaf of bread is not really what is meant by *buttering the bread*. Ultimately, large chunks of world knowledge seem to be involved, and the question is how to represent them. I do not think that this cannot be done, it just requires further work.[12]

The problem for Gärdenfors seems to be more severe. According to his single domain constraint for verbs, a verb refers either to the force vector or to the result vector, and so *butter*, being *prima facie* a result verb, would have to refer to the result vector of the event. However, if the verb also conveys the action of spreading, then it does seem also to specify the manner of the application of force, thereby invalidating the constraint. Now, this spreading is not lexicalized as a replacement, secondary manner meaning (cf. Gärdenfors 2014: 189) – it seems to be part of the basic, primary meaning.[13]

It seems, therefore, that *butter* is both a manner and a result verb, which refutes Gärdenfors's single-domain constraint. Also, Gärdenfors seems to underestimate the importance of "dot-actions" such as *reading* (although he is aware of them, cf. Gärdenfors 2014: 296, endnote 24): these actions, named as such by Pustejovsky, involve multiple domains – e.g. reading involves "the action of visually scanning a writing-bearing object, combined with the action of assimilating the information therein" (Jackendoff 2002: 374).

[12] Jackendoff (p. c.) points the way to go: the additional element of the meaning of *to butter* can be formulated as 'use butter in its proper function' or 'use butter, following its telic quale' (cf. Jackendoff 2010: 276).

[13] A reviewer disagrees. S/he adduces the example *spreading the butter by a putty knife or one's finger*. But these are still cases of spreading the butter by an instrument of adequate width, which is what the verb conveys. As for the reviewer's example *spreading the butter by spraying it on*, I would say that it is not really a case of spreading.

Ultimaltely, therefore, Jackendoff's analysis seems to come out on top – although it manifestly requires further elaboration. It also seems to be preferable to Gärdenfors's in terms of accounting for similarities between verb meanings, and accounting for similarity is, as we have seen, one of the main desiderata of Gärdenfors's approach. Whereas Jackendoff can account for these similarities in terms of sharing conceptual functions, Gärdenfors offers the "distances between underlying action vectors" (2014: 182). But Gärdenfors seems to miss the underlying similarity between *to butter* and *to pocket* (both involve 'causing something to come to be in a place', cf. Jackendoff 2002: 367), whereas Jackendoff can account for the simliarity between *walk* and *jog* (cf. Gärdenfors 2014: 182) in terms of SpS (though saying how exactly requires further work).

In conclusion to this section, both Gärdenfors's and Jackendoff's framework can be said to be preferable to the framework of formal semantics, whereas Jackendoff's approach seems to fare better than Gärdenfors's.

One may wonder[14] whether Jackendoff's and Gärdenfors's approaches could be represented in a common format. *Prima facie*, they could not, since Gärdenfors's notions are spatial and Jackendoff's are not. However, if Jackendoff accepted that his functions, such as GO or CAUSE, could be represented as image schemas, then a certain intertranslatability between his and Gärdenfors's framework could be achieved. I am not sure he would accept this.

5. Empiricism vs. nativism

Both Gärdenfors and Jackendoff account for meaning in terms of conceptual structure, and see word learning as the mapping of words into concepts. However, their respective takes on how concepts are acquired (and, therefore, words learned) are importantly different. Gärdenfors is an empiricist, whereas Jackendoff is a (moderate) nativist. I will now briefly present and discuss these two views. Since formal semantics accounts for meaning independently of concepts,[15] it will not figure in this debate.

Gärdenfors claims that "concepts can be built up from perceptual mechanisms" (2019: 451–452). He proposes two learning processes that account for how children learn concepts. The first process detects *invariants* in the sensory input, e.g. the solidity of objects or the force patterns that generate the structure of actions. On

[14] I am grateful to an anonymous reviewer for posing this question.

[15] But cf. Pietroski (2018).

the basis of these invariants, domains are constructed, in this case the object domain ("object category space" in the terminology of Gärdenfors 2014) and the action domain. The second learning process is the one that detects *covariances* between different dimensions of what is perceived to construct concepts. For example, we detect covariances beween having feathers and flying (and certain other properties) and we construct the concept of birds. In accordance with his criterion that a concept is represented as a set of regions in a number of domains (Gärdenfors 2000: 105), we see that, on this account, the concept BIRD is represented by regions in the object domain (having feathers) and the action domain (flying). This, according to Gärdenfors, is how concept formation proceeds. Word learning then comes in as learning that words refer to these clusters of regions. Gärdenfors (2000: 188) claims that "a theory of learning based on *associations* will construe the coupling between a linguistic expression and its cognitive meaning as just a special case of general learning" (italics in the original).

Jackendoff would disagree with the above. First of all, on his account, the concepts we learn are constructed out of a basic repertoire of innate concepts, amongst which is the concept OBJECT. Learning the concept BIRD then involves this innate concept. In other words, on 's account, some aspects of the domains have to be innate.

As for word learning, Jackendoff frequently points out that a word is a special kind of linking between a piece of phonology, a piece of syntax, and a piece of semantics (a concept). Pinker & Jackendoff (2005) point to many properties of words, such as their generic reference and their carrying syntactic features as an input to syntax, that make the knowledge of them different from general factual knowledge and consequently claim (2005: 215) that it is "difficult to hold that the capacity to represent and learn words is part of a general knowledge system ...".

This debate will not be decided here. Suffice it to say that when it comes to words, Jackendoff seems to be right that the linkage of phonology to meaning is a special kind of linkage that cries out for an innate guidance in order to be learned, so that this learning cannot be just an instance of general learning. As for concepts themselves, the issue comes down to whether the child could indeed construct concepts out of the flow of sensory input just by way of general mechanisms, as proposed by Gärdenfors. I concur with the nativist view that the stimulus is too impoverished to enable one to rapidly acquire the huge number of concepts we do acquire without innate chanelling.

A key notion for an empiricist is similarity, and so it is for Gärdenfors. It is defined by him as a function of distance in conceptual spaces. It plays a key role in

the prototype theory of concepts (something is classified as a C if it is sufficiently similar to the C-prototype). Since Jackendoff also accepts some form of the prototype theory, the question is whether he can account for similarity. As far as I know, Jackendoff does not offer an account of similarity, but it seems easy to construct one on the basis of his theory. Namely, Jackendoff analyses meanings in terms of *features* (meaning components), and similarity can then be construed as overlap of features. So, he is not at a disadvantage here with regard to the empiricist.

6. Internalism

In this section, I want to address another common commitment of Gärdenfors and Jackendoff: their semantic internalism. They are internalists not only in the standard sense that what is in the head determines reference (cf. Kallestrup 2012). Their internalism is more radical: for them reference is not even an extra-mental relation.

Gärdenfors constructs a meeting-of-minds semantics. He says (2014: 110): "my semantic theory builds on how the individuals construe the world in their minds and how they coordinate their construals". Further (2014: 92): "a 'meeting of the minds' will be that condition in which both individuals find themselves in compatible states of mind". Finally (2014: 108): "What makes communication possible is the capacity to establish similarity-preserving mappings between the conceptual spaces of the participants and to approach mutual fixpoints". Gärdenfors terms his semantics *sociocognitive* – according to it, meaning emerges in communicative interaction.

Jackendoff proposes something similar. For him, we refer to the world as conceptualized. He is impressed by our being able to refer to fictional objects, virtual objects (such as a square formed by four dots), social entities, auditorily percieved objects, tactile sensations ("the pain"), actions ("the running", "*that* was fast"), etc. He says, therefore, that "an entity's being in the real world is neither a necessary nor a sufficient condition for a speaker's being able to refer to it. Rather, the crucial factor is having conceptualized an entity of the proper sort" (2002: 304). It follows that that meaning is squarely in the head. However, people also "have a need to 'tune' their conceptualizations to those of others" (2002: 330), so his semantics can also be seen as a species of meeting-of-minds semantics.

Jackendoff (2002: 300) claims that "one cannot make naturalistic sense of intentionality", that this relation of aboutness, important for formal semantics, is a mystical relation. Decades of failed attempts to naturalize intentionality testify to his

being right. Indeed, I believe both he and Gärdenfors are basically right in their approach; it is just that they describe this approach somewhat infelicitously.

Gärdenfors (2000: 201) says that "the referents of words are identified with conceptual structures in people's heads", and Jackendoff would say the same thing. However, this is an unhappy way of putting it. Trivially, we use language to refer to the world. If I say "that table", I am referring to the table in front of me, not to my (or your) concept of a table. This is a commonsensical, even a conceptual, truth, that cannot be denied.

A better way of formulating Gärdenfors's and Jackendoff's approach in semantics is to say that no science can be made of the reference relation, if it is construed as a relation between words and external things. The science, which they have both made important contributions to, is of how people encode their construals of the world in their minds, and how they communicate these construals to each other.

7. Conclusions

In this paper I compared the formalized conceptualist approaches of Gärdenfors and Jackendoff against the backdrop of formal semantics. First I outlined some common commitments of Gärdenfors and Jackendoff, then I presented the basics of their theories, assessing specifically how they deal with the issues of lexical decomposition, compositionality, and reference and truth. After this I got down to the nitty-gritty of semantic analysis according to these theories. Finally, I discussed the nativism of Jackendoff as opposed to the empiricism of Gärdenfors, and I commented on their common internalism.

My overall conclusion is that the Jackendoffian approach is to be preferred to all others. Its basic commitments seem to put it on the right track (as opposed to formal semantics in some cases), and the details of the kind of semantic analysis it offers seem to place it above both Gärdenfors's framework and the formal semantic one (which it supersedes in terms of testable predictions). Finally, although I view Gärdenfors's and Jackendoff's common internalism as preferable to the externalist alternative, I believe that Jackendoff's nativism is more in accord with empirical (and theoretical) considerations than Gärdenfors's empiricism.

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GEOMETRIJA VS. ALGEBRA ZNAČENJA: GÄRDENFORS VS. JACKENDOFF

U ovom članku uspoređuje se Gärdenforsov geometrijski pristup značenju u prirodnom jeziku s Jackendoffovim algebarskim pristupom, i to na pozadini formalne semantike. U konačnici, tvrdi se da Jackendoffov teorijski okvir treba preferirati u odnosu na sve druge. Članak je organiziran kako slijedi. U prvom odjeljku, navode se teorijska gledišta

zajednička Gärdenforsu i Jackendoffu, te se ukratko argumentira da su na dobrom tragu. U drugom odjeljku, iznose se osnove dvaju teorijskih okvira koji su predmetom usporedbe, te se razmatra na koji se način nose s nekim središnjim temama semantike, naime s referencijom i istinom, leksičkom dekompozicijom i kompozicionalnošću. U trećem odjeljku, ulazi se u detalje toga kako Gärdenfors i Jackendoff zaista postupaju pri semantičkoj analizi, služeći se primjerom imenice i glagola (uklopljenog u rečenicu). U četvrtom odjeljku, razmatraju se dosezi Gärdenforsovog empirizma glede učenja riječi i stjecanja pojmova i uspoređuju se s Jackendoffovim umjerenim nativizmom, te se tvrdi da Jackendoffovom nativizmu treba dati prednost. U završnom odjeljku, komentira se semantički internalizam koji je zajednički obama okvirima.

Ključne riječi: značenje; geometrijski; algebarski; domena; funkcija.